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This report summarizes the tasks performed under Contract N00014-70-A-0166, Task 0023, during the period 1 July 1974 through 30 June 1975. The areas of work performed were upgrading of data processing systems, processing of environmental acoustic data for the SQUARE DEAL Exercise, acoustic model implementation, and technical support. A feasibility study of SUS multipath processing and analysis was successfully conducted.

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I. INTRODUCTION

The work described in this report was performed under Contract N00014-70-A-0166, Task 0023, during the period 1 July 1974 through 30 June 1975. The areas of work performed were an upgrading of the environmental acoustics (EVA) volume data processing system and procedures, volume processing of SUS and cw data from the SQUARE DEAL Exercise, the implementation of acoustic models on the ARL:UT computer system, and technical support.

A feasibility study of SUS multipath processing and analysis for bottom loss and arrival structure was completed. It was shown that the ACODAC data could successfully support this type of data processing and analysis.

II. SYSTEM MODIFICATIONS

A. Hardware Modifications

During the contract period, ARL:UT made a number of improvements to the analog playback system used to perform EVA data processing. The principal effort was the design and construction of a set of programmable amplifiers along with associated control circuitry. This unit, designated the gain interface unit, replaced the fixed gain amplifiers formerly used. Operated under joint computer/operator control, this unit eliminated the dynamic range limitations formerly encountered when digitizing ACODAC data. Using this unit at playback rates of 120:1 or more required the design and construction of high speed controllers to augment the digital output unit used to control the amplifier settings. This unit has significantly improved the quality of the digitized data and has also removed one of the most common sources of error, failure to accurately note gain settings.

The other major improvement to the EVA playback system was the purchase of a real-time analyzer (RTA). Previous work had shown that an RTA is essential for the proper calibration and configuration of this playback system. The RTA is also essential to the timely assessment of data quality, both before and during A/D conversion.

B. Software Modifications

The ARL:UT continuous wave processing system (CWPS) is a hardware/software configuration designed to perform narrowband analysis over a variable frequency range and a large volume of data. The system performs four tasks: A/D conversion, calibration, measurement, and display. This report will describe the system in terms of its application to data from the SQUARE DEAL Exercise. Parameters such as bandwidth, frequency range,

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resolution, and integration time can be readily altered to suit other applications.

The first task performed by CWPS is analog-to-digital (A/D) conversion of time series data. For the current application an ACODAC tape is played back at an 80:1 time compression, and a single hydrophone channel digitized on each pass.[1] The analog signal is low pass filtered (200 Hz) to prevent aliasing and high pass filtered (5 to 20 Hz) to minimize the effects of cable strumming. The filtered signal is then input to a programmable amplifier under joint computer/operator control. The gain is varied so as to maintain a signal level which best utilizes the dynamic range of the 12-bit A/D converter to which the signal is then input. Simultaneously, the ACODAC modified IRIG-C timecode is decoded to obtain time and gain-state information. Overload and calibration signals are detected by means of analog detectors.

The sample sync (400 Hz) is derived from the timecode carrier (50 Hz) by multiplication with a phase lock loop frequency multiplier. Using this sync, the signal is sampled and input to a CDC 3200 computer system. The computer checks each sample to ensure that it is not distorted by exceeding the range of the A/D converter. As an option, the operator can permit such "clipping," and usually will in the presence of shots. Any "clipped" data are flagged and then deleted in a later segment of the processing. The computer will also determine the peak and average amplitude of the data within each minute; this information is used to determine the desired amplifier setting for the data in the following minute. Finally, the data are stored on magnetic tape in a format designed to facilitate later processing, along with time, gain-state, clipping, overload signal detection, and calibration signal detection information. The computer constantly monitors timing

*In the following discussion, all frequencies and times are given in terms of the rate at which the data were recorded.

signals from various devices to ensure that overall time synchronization is maintained. Should any one of many possible problems be detected, the computer will terminate the process and inform the operator of the problem. After corrective action has been taken, processing resumes prior to where the problem was detected.

The second task performed by CWPS is calibration of the digitized data. This task is most readily understood in terms of the overall procedure. All of the data on a single channel from which measurements are to be obtained are digitized during a single pass. The external calibration sequence (delta functions) for this channel are digitized both before and after the digitizing pass; this redundancy is required for quality control. The frequency response of the entire record-duplicate-playback system is obtained from each set of calibration signals. The level during each minute of each of the internal (6 h) calibration sequences is also obtained from the digitized data. The fluctuations in these levels yield additional quality control information. Each of the signals within the external and internal calibration sequences is measured by means of a fast Fourier transform (FFT) in both the cw processing bandwidth (0.29 Hz) and the standard one-third octave bands. The frequency response, hydrophone sensitivity, absolute and measured levels of the internal calibration signals, and gain-state information are then combined to yield a set of frequency and bandwidth dependent conversion factors. These factors, along with gain information, are used to convert later measurements into absolute values. These conversion factors can also be a function of the ACODAC gain-state if sufficient frequency response information is available. If an internal calibration signal is included in the external calibration sequence, an in situ correction can be made. Neither of the above corrections could be made for the present application.

The third task performed by CWPS is determination, as a function of time, of the power within each of the desired frequency bands. For each minute of digitized data, five contiguous blocks of 4096 samples

within the minute are converted from the time domain to the frequency domain by a software FFT. The same FFT routine is utilized throughout the system. It uses the double algorithm with 24-bit integer arithmetic and includes automatic data scaling and internal reordering. (With a 4096-point transform of data sampled at 400 Hz, the resulting spectral lines will be separated by 0.098 Hz.) Once in the frequency domain, two types of measurements are obtained. For each cw signal, a narrowband (±1.0 Hz) about the source frequency is searched for its peak spectral line. The power in an even narrower band (0.29 Hz) centered about this peak is then determined. This technique of peak tracking is used to compensate for Doppler shift and variations in source frequency. The second type of measurement is determination of the power in a fixed frequency band, i.e., the power in a (3.0 Hz) noise band on each side of the cw signal. To facilitate the interpretation of the cw measurements, each of the standard one-third octave bands within the current frequency range (10 to 200 Hz) are also measured using this second method. All of these measurements are then converted to absolute values and output to magnetic tape along with time, gain-state, and data quality indicators.

The fourth and final task performed by CWPS is editing and display of the measurements. The measurements from any given transform are rejected if any one of the following conditions occurs:

(1) the data contain an overload signal;
(2) the data contain a calibration signal;
(3) a shot is detected in the data;
(4) the source was off during data collection;
(5) the data were clipped in the A/D converter;
(6) the two sets of ACODAC gain-states decoded from the time code for this minute are inconsistent;
(7) a digital tape parity error occurred during the handling of this data;
(8) the peak spectral line is not within ±0.2 Hz of the estimated source frequency.

Those measurements which survive the above editing are used to derive an acoustic noise estimator and signal power estimator, to be used in determining propagation loss. Attempts are made to minimize the effects of the ACODAC noise floor on the acoustic noise estimator. The editing is mostly intended for use with the cw measurements because the one-third octave bands may be heavily contaminated with shots, shipping noise, and ACODAC system noise. However, in the absence of shots, nearby shipping, and noise floor distortions induced by cable strumming, ambient noise measurements can be obtained.

Strict control of data quality is maintained throughout CWPS. Tight control is most essential during the first task, A/D conversion. This control begins with the A/D operator, who monitors the hardware by means of a series of optical displays, including a real-time analyzer and a computer generated status display. The CDC 3200 computer checks for errors on a much smaller time scale; this checking includes timecode monitoring and verification, signal amplitude monitoring, data flow monitoring, and overall synchronization. The computer also generates a permanent record of each error or operator interaction. Finally, overall consistency of each A/D run is verified by comparison of the frequency responses measured at the beginning and end of each run, and by comparing the levels of the internal calibration signals occurring throughout the run.

To summarize, the essential parameter values for application of CWPS to data from the SQUARE DEAL Exercise were:

Playback Rate:	80:1
Sample Rate	400 Hz (derived from 50 Hz timecode carrier)
Frequency Range:	10 to 200 Hz (adjusted to minimize strumming effects)
FFT Length:	10.24 sec (4096 samples)
FFT Rate:	5 contiguous transforms centered within each minute

Spectral Line Spacing:	0.098 Hz
cw Frequencies:	6
cw Signal Analysis Bandwidth:	0.29 Hz (peak centered)
cw Noise Bandwidth:	3.0 Hz (located on each side of the signal)
One-third Octave Bands:	12.6 to 158.5 Hz

A narrower cw analysis bandwidth would have been preferred; however, a high resolution study at ARL:UT determined that the maximum ACODAC frequency resolution across all channels was 0.2 Hz due to dynamic tape skew that occurs with a single time base. Future data can be processed with a narrower bandwidth if the recommendation of an independent time base on each channel is implemented.

III. ENVIRONMENTAL ACOUSTICS DATA PROCESSING

A large volume of data was processed by ARL:UT for the SQUARE DEAL Exercise. These data were recorded by ACODAC systems using cw and SUS sources. Selected data sets from four ACODAC tapes were processed for propagation loss and signal excess as outlined in the SQUARE DEAL data analyzer plan. A total of 106 hydrophone days of cw data and 50,000 hydrophone shots were processed.

These data products were forwarded to the SQUARE DEAL Exercise Chief Scientist for inclusion in the Environmental Acoustics summary report.

IV. ANALYSIS AND REPORTING

A. Acoustic Model Implementation

ARL:UT received documentation and computer software for the FACT (ONR/AESD) and the FFP (NUSC) propagation models, for use in the data processing assessment. The FACT model software was converted to execute on the ARL:UT CDC 3200 computer and the FFP software was converted to execute on the UT Austin CDC 6600 computer. The models were then tested for proper implementation and accuracy.

The FACT model was extensively used during the SQUARE DEAL Exercise volume data processing to assess the results in a timely fashion.

B. SUS Multipath Analysis

In acoustic measurements in the deep ocean, the contribution of bottom interacting rays is often an unknown factor. To assess this contribution, the individual rays must be traced from source to receiver--a complex multipath. Therefore a feasibility study was done of a computer measurement system that would analyze individual shot multipath arrivals; propagation loss for individual arrivals has been studied and demonstrated on actual ACODAC data.

Several steps are required in a multipath analysis. In addition to spectral analysis by FFT, it is necessary to identify component arrivals to within approximately 100 msec, to separate overlapping, or nearly overlapping, arrivals, and to identify arrivals in terms of number of turning points, surface and bottom reflection angles, etc. In addition, if a measurement of bottom loss is needed, a propagation model is used to obtain bottom loss from the measured arrival signal levels. Prototype computer software has been implemented for signal and spectrum display,

spectral analysis, and propagation modeling. The information and experience gained from this work can be applied to the development of an efficient measurement system.

Several computer programs are available to display signals and spectra in varying detail. These were designed to provide "working" outputs for assessment of the procedures. In addition to plots, printed outputs were also used to gain insight into the nature of the signals being studied. Any further work would be to eliminate the complicated plotting and manual measurement of arrival times and durations.

A system to measure the propagation loss of individual arrivals, once the arrival times have been specified, has been implemented and successfully tried on a few series of shots from the CHURCH ANCHOR Exercise and the SQUARE DEAL Exercise. The ACODAC overloading problem made it very difficult to find an appropriate series of shots that were not overloaded and that had strong signal-to-noise ratio. Using the FFT, spectral levels in bands approximately 1 Hz wide from 10 Hz to 300 Hz were determined; from these, propagation loss in one octave or one-third octave bands was calculated.

The ability to identify individual ray paths in a particular arrival is necessary for multipath analysis to be valuable. Work done at ARL:UT for a separate, but related, research program has yielded a computer program that will determine the exact eigenray paths between source and receiver, assuming a range invariant sound velocity structure and depth. This achievement goes considerably beyond the ability to trace out a suite of rays with fixed launch angles. Outputs of the eigenray program include arrival times and bottom reflection angles, if the rays are not refracted. Information such as this will be integrated into the multipath analysis system.

C. CHURCH ANCHOR Exercise

ARL:UT participated in the final draft preparation of the Environmental Acoustics summary report under guidance of the Chief Scientist. A technical report on SUS propagation loss was issued.

D. SUS Diagnostic Plan

The ARL:UT work outlined in the SUS diagnostic plan developed by G. Ellis (ARL:UT) and M. Weinstein (USI) was completed. A summary of the results was presented in sponsor briefings and in a technical report.

E. Reports Resulting from Research

Phillip D. Huddleston and L. Ross Fisher, "Documentation of Program Cheklite," Applied Research Laboratories Preprint No. 74-48 (ARL-P-74-48), Applied Research Laboratories, The University of Texas at Austin, 16 December 1974, 21 pages.

Michael W. Ohlendorf and H. Wayne Pitman, "Documentation for Program Deckform," Applied Research Laboratories Preprint No. 74-49 (ARL-P-74-49), Applied Research Laboratories, The University of Texas at Austin, 18 December 1974, 36 pages.

Aubrey L. Anderson, "CHURCH ANCHOR Explosive Source (SUS) Propagation Measurements" (U), Applied Research Laboratories Technical Report No. 74-53 (ARL-TR-74-53), Applied Research Laboratories, The University of Texas at Austin, December 1974, 258 pages. CONFIDENTIAL

14 August 1979

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Unavailable	Unavailable	SELF-TENSIONING ACOUSTICAL HORIZONTAL LINE ARRAY (SPRAY) DATA ANALYSIS. FINAL REPORT OF BEARING STAKE TESTS JANUARY THRU MARCH 1977. VOLUME IVB. DATA POINTS 10, 11 AND 12 RAW DATA	Sanders Associates, Inc.	790109	ADC017579	U
ARLTR7924	Mitchell, S. K., et al.	ANALYSIS OF ACOUSTIC BOTTOM INTERACTION IN BEARING STAKE (U)	University of Texas, Applied Research Laboratories	790223	ADE001369; NS; ND	U
TIU1886502F	Eichenberger, D.	REPORT FOR CHURCH STROKE II OCEANOGRAPHIC SERVICES	Texas Instruments, Inc.	790326	ADB036751; ND	U
Unavailable	Unavailable	FINAL REPORT, 1 NOVEMBER 1976-31 DECEMBER 1978	Xonics, Inc.	790430	ADB037987	U
Unavailable	Mitchell, T. M.	PREMOBILIZATION OF R/V INDIAN SEAL	Texas Instruments, Inc.	790531	ADB039703	U
Unavailable	Hays, E. E.	ACODAC AMBIENT NOISE PROGRAM	Woods Hole Oceanographic Institution	790601	ADB040404	U
LRAPPR79029	Unavailable	INTRODUCTION TO THE LRAPP ENVIRONMENTAL-ACOUSTIC DATA BANK (U)	Naval Ocean R&D Activity	790601	ADB041066; NS	U
USRD NO. 4807	Unavailable	MEASUREMENTS ON AQUADYNE MODEL AQ-1 ELEMENTS FOR THE UPGRADED LAMBDA ARRAY	Naval Research Laboratory	790802	ND	U
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